Psychological Barriers in the Eurozone's Stock Indices

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Biographical Note

Cristiano Pereira was born in Viana do Castelo, Portugal in December 15th, 1991. He received his bachelor degree in Economics from Faculdade de Economia da Universidade do Porto in 2012. In the same year he joined the Master in Finance course at the same university, which he is currently studying.

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Abstract

Almost every week stock indices breaking through round numbers are announced in the main financial news media, but do these events have impact in the market? According to mainstream financial theory they do not, but there are several empirical studies that say the opposite as well as several reasons are appointed to justify this phenomenon known as Psychological Barriers; moreover, daily traders use psychological barriers in technical analysis trading strategies.

Since the early 1990's the existence of psychological barriers, i.e. the fact that round numbers act as barriers impacting the behavior and expectations of investors, have been empirically tested and have been found in several asset classes, regions and time samples. However, up to today there is no published study in several of the main European stock indices. Moreover, there are little studies that include a time frame after the 2008 crisis.

Therefore in this thesis we are the first to perform a wide study on the existence of psychological barriers in the Eurozone founding countries (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Portugal, Spain and The Netherlands) main stock indices.

We performed a uniformity test, a barrier proximity and hump tests as well as conditional tests and conditional differences tests using a sample containing the main stock index in each of the previously mentioned countries since their creation until the end of 2013.

We found evidence of psychological barriers in the Finnish OMXH25, the German DAX 30, the Greek FTSE/ATHEX LARGE CAP and the Dutch AEX. Within the other nine indices the results are inconclusive. We also find that the impact of psychological barriers on those four indices was less than 10 days; further research on that matter is clearly recommended since no study concluded that for any asset class before, to our knowledge.

Key-words: psychological barrier, stock index, behavioral finance, Eurozone.

JEL codes: G12; G14

1. Introduction

On August 25th, 2014 the Financial Times website edition reported: "S&P 500 passes 2,000 for the first time" (Mackenzie, 2014b) and the day after another article entitled: "Little fanfare as S&P 500 passes 2,000". And in this second article it started by stating: "When the S&P 500 reached 1,000 for the first time in February of 1998, Kenny Polcari was trading equities for ICAP from the floor of the New York Stock Exchange. The excitement was palpable. 'No one was popping champagne bottles, but it felt like they were,' says Mr. Polcari, now a director at O'Neil Securities but still running his business from the NYSE floor. 'There was an energy in the economy – an energy that is interestingly enough absent today.'" (Mackenzie, 2014a).

Breaking through a round number of hundreds or thousands is regarded as important information for the market, as the previous news and thousands of other every year state. And contrarily to what classical finance states, the admiration in that second article was that the market had not reacted to that round number, or in other words to that psychological barrier.

"[Psychological] barriers would manifest themselves by the market finding it difficult to break through the barrier to a different level." p. 2017 (Aggarwal and Lucey, 2007) A psychological barrier occurs when it is more difficult to move beyond or below a specific price than elsewhere. For example, if the index is 950 and an event impacts the market which intrinsic value for that index is +30, the index moves to 980. However, if the index is 970 or 975 and the same event occurs the index is more likely to remain below 1000 than to move to 1000 or 1005. This is due to the fact that market participants regard 1000 as psychologically important and so require a greater positive event to pass it. The same applies with a negative event (Bahng, 2003).

Therefore, if these round numbers have an effect on the behavior of the price it is clear that the market is not efficient as the number by itself has nothing to do with the value of the asset or the expectations of the investors. Indeed, we do know that markets may not be efficient (Shleifer and Vishny, 1997); there are persistent psychological biases, Hirshleifer (2001); and investors may not choose to maximize their wealth due to cognitive limits, (Sonnemans, 2006; Preece, 1981). So, psychological barriers are in fact possible and even plausible; as well as present an additional proof that markets are not efficient.

The psychological barriers phenomenon has been studied since the beginning of the 1990's, mainly on stock indices, but also on futures, FOREX and commodities. However, only some of the main European stock indices have been studied. Therefore this study will focus on applying the most recent approaches to the phenomenon to the main stock index of each of the founding countries of the Eurozone (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Portugal, Spain and The Netherlands) and to the main stock index for the Eurozone.

The recent study performed by Aggarwal and Lucey (2007) on the existence of psychological barriers on gold prices will be the main guideline. Their study enclosed the three main tests on psychological barriers as well as their approach is suitable to be implemented on stock indices.

Therefore, the main purpose of the study is to discover if there are psychological barriers on the thirteen previously mentioned indices.

As stated before, this study enlarges the knowledge about psychological barriers, since it is the first time some of those markets are under study for it; as well as it is the first one, to our knowledge, to use data that includes the 2008 financial crisis period.

Furthermore, to achieve the reports' goal, a distribution uniformity test will be performed at first. This test intends to test if any number is equally probable of appearing. A barrier proximity and barrier hump tests will follow to attest the previous one's conclusions and to test if the unequal distribution is caused by the round numbers or numbers near round numbers having a significant different probability of appearing. Finally, a conditional effects test will be performed to identify the impact of the psychological barriers on the return and variance of the stock indices; here we will test if there are significant differences in mean return and variance before and after crossing a barrier.

We found evidence of psychological barriers in the Finnish OMXH25, the German DAX 30, the Greek FTSE/ATHEX LARGE CAP and the Dutch AEX. Within the other nine indices results are inconclusive. We also find that the impact of psychological barriers on those four indices was less than 10 days; further research on that matter is clearly recommended since no study concluded that for any asset class before, to our knowledge, since none has compared two different timeframes for the Dummy variable.

The remainder of this thesis is organized in the following manner: in the next section we review the literature presenting the market efficiency question, reasons for the existence of psychological barriers and similar empirical studies; in the third chapter we present the methodological aspects where the steps of the study, the data and the empirical study methodology are laid; in the fourth chapter we present and analyze our results; conclusion in the fifth and references in the sixth follow.

2. Literature Review

Market efficiency is one of the cornerstones of finance since the 1970's, however since the 1990's it has been put into question. The existence of psychological barriers is one of the several biases where human's heterogenic nature and limited cognitive capabilities produce market inefficiencies. This chapter will draw the pathway of that evolution in theoretical and empirical finance; followed by the reasons for the existence of psychological barriers as well as several empirical studies (similar to this one) that found the existence of this phenomenon in different asset classes, regions and time frames.

2.1 Market Inefficiency

Since Fama (1970) introduced the market efficiency theory, it remained almost uncontested until the 1990's, when several empirical studies proved the existence and persistence of inefficiencies.

Indeed, even Simon (1955) had already introduced the idea that agents may not be able to maximize their utility but instead look for the good enough solution, as they are not capable of calculating every outcome as well as not all information is available or possible to achieve given time constraints by them; and so they would not act in perfect rationality. Therefore, there are market inefficiencies that can only be corrected by fully rational arbitrageurs.

However, Shleifer and Vishny (1997) proved the existence of limits to arbitrage (like fundamental risk, noise trader risk, implementation costs, and they even face psychological biases) so it is possible to observe mispricings in the financial markets. Moreover, Hirshleifer (2001) proved there are several psychological biases that are persistent in time within the financial markets; in other words they are not exploited/corrected by arbitrageurs.

As a clear example of limited cognitive capacity, George and Hwang (2004) show that the 52-week high price explains most of the profits from momentum strategies of investment.

In addition, Feng and Seasholes (2005) even proved that experience and sophistication are not capable of eliminating behavioral biases on professional traders.

2.1.1 Price Clustering

Price clustering occurs when a set of prices is observed more frequently that the rest, given that the underlying value is uniformly distributed by the admissible set of prices (Aitken *et al.*, 1996).

Niederhoffer (1965) theoretically deducts that in an efficient market, prices should be uniformly distributed in all possible pricing grids. However, several empirical studies, like Harris (1991) prove this does not happen in reality; prices cluster.

There are several reasons for price clustering. One of those possible reasons is that investors perceive certain prices as barriers or providers of relevant information; in other words, prices cluster due to the existence of psychological barriers (Mitchell, 2001).

2.2 Psychological Barriers' Reasons

Psychological price barriers may be caused by several reasons, which will now be explained. Most of them come from the field of anchoring (2.2.1), aspiration levels (2.2.2), odd pricing (2.2.3), cost efficiency (2.2.4) and there is even a possible rational explanation (2.2.5).

2.2.1 Anchoring

Along with other commonly used heuristics, Tversky and Kahneman (1974) document the existence of the anchoring bias, which is the fact that people when estimating the value of assets tend to use an initial quick estimate value and when so, this initial value impacts the final estimate creating an error of estimation. The fact is that people perform insufficient adjustment from their initial estimates and, thus, different initial values provoke different final values.

Moreover, in the book "Irrational Exuberance" Shiller (2005) states that while making estimates, in the absence of clear agreement the nearest round number acts as an anchor and so they tend to relate on this number as a good proxy.

Westerhoff (2003) built a model where agents interact in the FOREX market either expecting that the rate tends to the (perceived) fundamental value or the rate continues its current trend. Moreover, based on Shiller (2005), Westerhoff (2003) considers agents rely on the nearest round number as a proxy of the fundamental value.

Given this set, Westerhoff (2003)'s model predicts excessive volatility as well as that exchange rates tend to fluctuate around their perceived fundamentals. Thus, the limits of this band are perceived as support and resistance levels; in other words, there are psychological barriers in this market.

2.2.2 Aspiration Levels

Sonnemans (2006) raised attention to the fact that investors when buying a stock may already have defined their selling price, and considering bounded rationality it is likely that those limit sell offers are round numbers. In the same line, Simon (1955) built a model aiming to explain investors' selling decisions and, indeed, he considers that since investors are not able to maximize their utility due to information, time and calculation limitations they would be likely to set a round number near to their estimate as a limit sell offer when they purchase the stock. Therefore, a larger number of transactions around round numbers should occur.

Moreover, Cooney Jr *et al.* (2003) empirically proved that trades on the NYSE place more limit orders on even prices.

2.2.3 Odd Pricing

Holdershaw *et al.* (1997) documented that 97% of the prices in home-drop advertising material, and all advertising displayed in two free weekly newspapers, and the local daily (Manawatu Evening Standard) ended in either 0, 5 or 9. Moreover, Stiving and Winer (1997) prove that due to the use of 9 ending numbers there are level effects (consumers may underestimate the value of a price) and image effects (consumers may infer meaning from the right-hand digits).

Another example, in the banking sector Kahn *et al.* (1999) study shows empirical support to the fact that banks tend to set rates at integers and that rates are "sticky" at these levels, as rates are found more often just above than just under integers than below.

In addition, Brenner and Brenner (1982) shed light to the fact that humans may memorize in a way that gives higher importance to the first digit of each number as it is the most important and so compare two numbers in a left-to-right manner. This procedure is considered by the authors to be very effective.

These marketing and psychological studies show that in the stock market a price of 20 would be considered much higher than 19.9, as Sonnemans (2006) concludes. In other words, although the difference between 14.9 and 15 is the same as 14.2 and 14.3, the first is perceived by humans to be greater than the second.

2.2.4 Cost Efficiency

Closely related to the odd-pricing theory, Preece (1981) proves that people tend to simplify the information level while mentally processing numbers, this enables them to produce a quicker and more cost effective judgment. Takayanagi *et al.* (1995), show that, effectively, people perform comparisons and calculations faster when using round numbers.

Indeed, Hornik *et al.* (1994) find empirical evidence that round numbers are used more often than what is expected randomly, as well as, round numbers are more common in higher values.

Sonnemans (2006) approaches the fact that people tend to prefer round numbers as they are more comfortable: easy to calculate, decreased probability of mistakes and limits the informational load. However, risk of mistakes in the number in financial transactions is very low and sometimes people prefer non-round numbers, as for example in lotteries.

2.2.5 The Rational Explanation

It may seem strange, but there is a rational possible explanation for psychological barriers. Taking the odd pricing and cost efficiency explanations as baselines, Harris (1991) reaches the informational equilibrium pricing theory which states that investors will increase precision in prices when negotiating if the cost of acquiring the more precise information, and due to the increase in the time needed to negotiate, are paid off by the benefits for them due to having this higher precision; in other words, it is a trade-off between the cost of precision and the benefits from it.

However, even if this is a rational explanation to phenomenon as it relates time and cost efficiency to the effect, it does not explain why it only happens in round numbers as well as it does not explain why people behave differently.

2.3 Empirical Studies

In this section, we will explain the main tests made and results obtained within the last two decades from empirical studies on psychological barriers, since the first studies on this phenomenon in the early 1990's.

2.3.1 Stock Indices

Donaldson and Kim (1993) prove there are psychological barriers in the DJIA daily closing prices between October 14th, 1974 and May 18th, 1990. Indeed, within their sample, the Dow Jones Industrial Average (DJIA) closes fewer times, on average, in the neighborhood of 100's level round numbers than elsewhere. Moreover, the DJIA conditional returns are negatively correlated with those M-values. Given these two results, the authors conclude that DJIA prices' upward and downward movements are restricted by barrier level, but after crossing these barriers, the index registers higher than usual upward and downward movements. It is also important to note that the author ran several computer based random variables and did not find the same behavior as in the DJIA.

Koedijk and Stork (1994), in one of the first studies on psychological price barriers, use a regression (dummy) approach on a sample containing the daily middle rates (average of bid and ask rates) between January 1st, 1980 and February 28th, 1992 for the Brussels Stock Exchange (Belgium), the FAZ General (Germany), the Nikkei Stock Average 225 (Japan) and the Standard and Poors Composite (United States). They also use the FTSE-100 (United Kingdom) between January 2nd, 1984 and February 28th, 1992. The study concludes for the existence of barriers, but that there is no evidence of predictability power.

Ley and Varian (1994) performed uniformity tests and concluded that although distribution was not uniform, there is no predictability power on the Dow-Jones Industrial Average (DJIA) daily closing prices between January 1st, 1952 and June 14th, 1993 due to psychological barriers.

Cyree *et al.* (1999) used daily closing values of the Dow Jones Industrials Average, the S&P 500, the TSE 300 (Toronto), the CAC 40 (Paris), the DAX (Frankfurt), the Hang Seng (Hong Kong), the Nikkei 225 (Tokyo), and the Financial Times UK Actuaries

(London). All the series in their data set finish on the end of 1994. They performed a uniformity test as well as a GJR-in-mean model to study the conditional mean return behavior and their results varied between indices, but they still reached several stylized facts indicative of the existence of psychological barriers that occur in most or all of the indices.

The first one is the fact that upward movements through price barriers tend to produce a positive impact on the conditional mean return, but downward movements tend to produce an indeterminate impact (six of the eight indices register statistically significantly higher returns after crossing a barrier in an upward move, as well as two indices have significantly lower returns after a downward crossing). This finding is in line with Aggarwal and Lucey (2007).

The second one is the fact that conditional variance tends to be higher in sub-periods prior to crossing a price barrier than in sub-periods after crossing a barrier (seven of the eight indices have some time of significant difference of conditional mean before and after crossing a barrier, but only the DJIA and the Nikkei are consistently significant in the case of both upward and downward movement).

Bahng (2003) tests the existence of 100's and 1000's psychological barrier in the South Korea (KOSPI), Taiwan (Taiwan Weighted), Hong Kong (Hong Kong Hang Seng), Singapore (Straits Times Index), Thailand (Bangkok S.E.T.), Malaysia (Kuala Lumpur Composite), and Indonesia (Jakarta Composite) stock indices, using daily closing prices between 1990 and 1999. Using barrier hump and proximity tests they only found clear evidence of psychological barriers within the Taiwan Weighted index.

2.3.2 Futures and Options

Jang *et al.* (2012) analyzed 15-minute interval historical values of the S&P 500 and VIX indices between July 8th, 2011 and January 19th, 2012 (the VIX was used to analyze the volatility of the S&P 500). Performing both a uniformity test and barrier proximity and hump tests, they concluded the S&P 500 behaves differently around psychological barriers (100's), especially in terms of volatility, which is in line with other studies. Therefore, they improved an option pricing model, for European call options on the S&P 500 by inputting the psychological barrier influenced expected volatility. They divided the model in two, depending if the index attained a barrier before or after maturity.

Their new option pricing model performed better than the Black-Scholes and the Constant Elasticity of Variance models in terms of calibration since it produced lower values of root mean squared errors; as well as in terms of hedging, since it generated lower dollar-value hedging errors than the two others.

Schwartz *et al.* (2004) examined if there was price clustering in the open outcry futures markets and found the S&P 500 futures contract prices tend to cluster at pricing increments of x.00 as well as of x.50 along trading day. Moreover, clustering was higher in opening prices and closing prices than in settlement prices. If prices cluster around these increments, there are psychological barriers.

Chen and Tai (Date Unknown) found psychological barriers in the three nearest futures contracts of the Taiwan Capitalization Weighted Stock (TWSE) Index: Index Futures (TX), Finance Sector Index Futures (TF) and Electronic Sector Futures (TE) from January 4th, 2000 to December 31st, 2009.

2.3.3 Gold Market

Aggarwal and Lucey (2007), using a sample of daily London AM fix gold between January 2nd, 1980 and December 31st, 2000 and COMEX cash and futures gold between January 2nd, 1982 and November 28th, 2002, perform uniformity (Z-test) and barrier (regression tests using possible barriers as dummies) tests for 1's, 10's and 100's levels values. From which they get evidence of the existence of psychological barriers in gold price series nearby 100's round numbers.

In addition, they conduct conditional effects test, with GARCH estimation, and conclude these barriers provoke important effects on the conditional mean and variance of the gold price series. They register that the bigger impact in the variance of returns occurs while in the vicinity and crossing a psychological barrier in an upward movement.

Moreover, they perform the same study for intra-day (15 minutes interval) gold between August 28th, 2001 and September 1st, 2003 and find no evidence of psychological price barriers.

2.3.4 Bond Market

Burke (2001), using a uniformity test as well as a barrier proximity hump tests, found psychological barriers on United States Treasury benchmark 30, 10, 5 and 2-year bonds 0.25% values on a sample between January 4th, 1983 and January 10th, 2000 daily closing yields.

3. Methodological Aspects

In this chapter we present the methodological aspects of the study like the data, construction of series and the tests used.

3.1 Data

The study uses daily closing prices of the following 13 stock indices (see table 1). All data was obtained from Thompson Reuters DataStream. Starting dates are different since we used the data of each index since their first trading day (available on DataStream).

Table 1 - Data Used in the Study

Country	Stock index	Starting date	Ending date
Austria	ATX	January 7th, 1986	December 31st, 2013
Belgium	BEL 20	January 2nd, 1990	
Europe	EURO STOXX 50	December 31st, 1986	
Finland	OMXH25	May 3rd, 1988	
France	CAC 40	July 9th, 1987	
Germany	DAX 30	December 31st, 1964	
Greece	FTSE/ATHEX LARGE CAP	September 23rd, 1997	
Ireland	ISEQ 20	January 2nd, 1998	
Italy	FTSE MIB	December 31st, 1997	
Luxembourg	LUXX	January 4th, 1999	
Portugal	PSI 20	December 31st, 1992	
Spain	IBEX 35	January 5th, 1987	
The Netherlands	AEX	January 3rd, 1983	

From this point on we will use the country instead of the index to designate each series, making it easier for the reader to analyze our results and relate the tables, since the names of the countries are more intuitive. Table 2 presents the summary of the statistics of the used data.

Table 2 - Summary Statistics of the Data Used

Country	*N*	Return series				Level series	
		Mean	Std. Dev.	Skewness	Kurtosis	Maximum	Minimum
Austria	7300	0.000009	0.000467	-0.14005	14.4253	4981.87	434.26
Belgium	6260	0.000004	0.000247	0.55278	17.8109	4756.82	928.57
Europe	7044	0.000007	0.000331	-0.43372	31.8836	5464.43	615.90
Finland	6695	0.000014	0.000903	0.78875	34.1112	3502.48	174.25
France	6908	0.000004	0.000253	-0.38589	34.8420	6922.33	893.82
Germany	12783	0.000009	0.000519	0.55938	16.2396	9589.39	319.93
Greece	4245	-0.000002	0.001784	0.98993	37.9344	3301.69	169.88
Ireland	4172	0.000014	0.001164	-0.35837	18.4020	1575.32	286.68
Italy	4174	0.000000	0.000032	0.11526	11.8689	50108.56	12362.51
Luxembourg	3911	0.000006	0.000482	-0.52095	15.3803	2586.03	639.86
Portugal	5478	0.000002	0.000071	-0.16431	13.5654	14822.59	2917.56
Spain	7041	0.000003	0.000126	-0.05759	22.3159	15945.70	1873.58
The Netherlands	8086	0.000125	0.003692	0.43016	46.8860	701.56	45.15

3.2 Empirical Study Methodology

There are mainly three types of methods that are used to test the existence and impact of psychological barriers. The first one is uniformity test, the older one, firstly introduced by Donaldson and Kim (1993) consists of a test of the uniformity of M-values in a given asset, if the distribution is not uniform, there is the possibility of existence of psychological barriers. The second one, are the barrier tests (barrier hump and barrier proximity), also introduced by Donaldson and Kim (1993), test if the uniformity is due to a different distribution of M-values around round numbers. The third one, the conditional effect test focuses on the impact of the barrier and, thus, tests if crossing the barrier on an upward and downward movement has different impact on return and variance; Cyree *et al.* (1999) were the pioneers of this approach.

Further technical details about these three types of tests are described on the "3.3 Empirical study consideration" since in this study we will use the three approaches.

The study will use the same tests as Aggarwal and Lucey (2007) and Jang *et al.* (2012) used since they convey all the mainstream studies on psychological barriers and the more recent innovations. Other older studies, on the basis of these two could be also used for further clarification.

3.2.1 M-values

M-values at the 100's level are the values of these integers that range between 00 and 99, in other words, they are the round numbers at which it is studied the likelihood of a psychological barriers (Koedijk and Stork, 1994).

a) M 0.1 is set as,

$$M0.1 = [P_t * 100] \, mod \, 100 \tag{3.1}$$

Where P_t is the quote, $[P_t * 100]$ is the integer part of $P_t * 100$ and mod 100 denotes reduction modulo 100. For example, if quotes are 1352.25 and 459.98, M 0.1 are 25 and 98.

b) M 1 is set as,

$$M1 = [P_t * 10] \, mod \, 100 \tag{3.2}$$

Where P_t is the quote, $[P_t * 10]$ is the integer part of $P_t * 10$ and mod 100 denotes reduction modulo 100. For example, if quotes are 1352.25 and 459.98, M 1 are 22 and 99.

c) M 10 is set as,

$$M10 = [P_t] \, mod \, 100 \tag{3.3}$$

Where P_t is the quote, $[P_t]$ is the integer part of P_t and mod 100 denotes reduction modulo 100. For example, if quotes are 1352.25 and 459.98, M 10 are 52 and 59.

d) M 100 is set as,

$$M100 = [P_t] \, mod \, 1000 \tag{3.4}$$

Where P_t is the quote, $[P_t]$ is the integer part of P_t and mod 1000 denotes reduction modulo 100. For example, if quotes are 1352.25 and 459.98, M 100 are 352 and 459.

3.2.2 Uniformity Tests

As introduced by Ley and Varian (1994), the daily values of each index or stock will be regressed and then a Kolmogrov–Smirnov Z statistic test for uniformity will be performed for M-values of M 0.1, M 1, M 10 and M 100. Within this test it is considered that H0: uniform distribution and H1: non uniform distribution.

However, the result of this test is not sufficient by itself to demonstrate the existence of barriers as Ley and Varian (1994) proved, the numbers may not be uniformly distributed and still there are no barriers. Moreover, De Ceuster *et al.* (1998) state that while the series grows the interval between barriers widens and so the distribution of digits and their frequency of occurrence stops being uniform.

3.2.3 Barrier Tests

Donaldson and Kim (1993) introduced the barrier tests type to study the existence of psychological barriers in the Dow Jones Industrial Average. Therefore, when there are no barriers the distribution of each M-value should be the same, therefore they use the distribution function of the M-values to study the existence of psychological barriers.

There are two types of barrier tests: the barrier proximity test and the barrier hump test, which will be now explained.

a) Barrier proximity test

Burke (2001), following Donaldson and Kim (1993), uses a barrier proximity test, which will test the frequency of occurrence of M-values near the psychological barrier. The same approach will be followed here. Therefore, the following regression will be run.

$$R_t = \ln\left(\frac{P_t}{P_{t-1}}\right)/d_t \qquad (3.5)$$

F(M) equals the frequency with which the index class with its two last digits in cell M, minus 0,01 (the expected value of each value in an uniform distribution is 1%, we subtract one so the expected is 0);

D is a dummy variable that takes the value one if:

Scenario1: the values 00 occur, and zero otherwise;

Scenario 2: the values 98, 99, 00, 01 and 02 occur, and zero otherwise;

Scenario 3: the values 95, 96, 97, 98, 99, 00, 01, 02, 03, 04 and 05 occur, and zero otherwise.

ε is regressed as a standard normal.

If β turns out to be a negative (and significant) value, it represents that the frequency of occurrence is lower than normal and so we are in the presence of a barrier. Otherwise, we are not in the presence of a barrier.

b) Barrier hump test

Burke (2001) also uses a barrier hump test. Donaldson and Kim (1993) note that the distribution of the M-values should follow a hump distribution. Therefore, Burke (2001) regresses the M-values frequency to a quadratic equation. The same approach will be followed here.

$$F(M) = \alpha + \delta M + \gamma M^2 + \varepsilon \tag{3.6}$$

F(M) equals the frequency with which the index class with its two last digits in cell M, minus 0,01 (the expected value of each value in an uniform distribution is 1%, we subtract one so the expected is 0);

M represents the values of the M-values between 00 and 99;

ε is regressed as a standard normal.

If γ is a negative (and significant) value then we are under the presence of a psychological barrier, since that is what would produce the expected hump shape. Otherwise, there are no psychological barriers of the level under study.

3.2.4 Conditional Effects Tests

Cyree *et al.* (1999) among all the other studies that follow them (including (Aggarwal and Lucey (2007)) use a GARCH (1,1) model to analyze the conditional effects, considering it to be the best one to model index return dynamics. They also introduce dummy variable to study the barrier region.

After a couple of OLS regressions and autocorrelation tests as well as comparison with GARCH (1,1) regressions we decided to the exact same approach here.

Aggarwal and Lucey (2007) use a 5 days period for their dummies, but Cyree *et al.* (1999) use 10 days, so we will be doing both.

The four hypotheses tested on this part are:

H1: There is no significant difference in the conditional mean return before and after an upward crossing of a psychological barrier;

H2. There is no significant difference in the difference in conditional mean return before and after a downward crossing of a psychological barrier;

H3. There is no significant difference in the difference in conditional variance before and after an upward crossing of a psychological barrier;

H4. There is no significant difference in the difference in conditional variance before and after downward crossing of a psychological barrier.

To do so, we, following Cyree *et al.* (1999) use four dummies for periods in the neighborhood of crossing the barrier as explanatory variables of the return of each index. Moreover, following previous studies, and as stated before, we use a GARCH 1,1 model for the variance of the residual.

$$R_t = \beta_1 + \beta_2 BD_t + \beta_3 AD_t + \beta_4 BU_t + \beta_5 AU_t + \varepsilon_t \tag{3.1}$$

$$\varepsilon_t \sim N(0, V_t) \tag{3.8}$$

$$V_t = \alpha_1 + \alpha_2 V_{t-1} + \alpha_3 \varepsilon_{t-1}^2 + \alpha_4 BD_t + \alpha_5 AD_t + \alpha_6 BU_t + \alpha_7 AU_t + \eta_t \tag{3.2}$$

R is the logarithmic return calculated as:

$$R_t = \ln\left(\frac{P_t}{P_{t-1}}\right)/d_t \tag{3.3}$$

P_t is the daily quote and d_t is the duration (in trading days) between t and t-1;

BD is a dummy variable that takes the value one in the five or ten closing daily values before approaching a barrier on a downward movement;

AD is a dummy variable that takes the value one in the five or ten closing daily values after approaching a barrier on a downward movement;

BU is a dummy variable that takes the value one in the five or ten closing daily values before approaching a barrier on an upward movement;

AU is a dummy variable that takes the value one in the five or ten closing daily values after approaching a barrier on an upward movement;

If markets are efficient one would expect the values of these dummies to be 0 both in the return and in the variance situations.

The dummy values will then be compared to check if there are return differences from approaching a barrier on an upward and downward movement. To do so we will perform a Wald test on the difference between each of the two compared variables, following Aggarwal and Lucey (2007).

4. Empirical Study

In this section we present the results of our study followed by an analysis of each test's results.

4.1 Uniformity Test

Table 3 (in page 20) shows the results of the uniformity tests. Apart from the Greek index M 0.1, M 1 and M 10 levels we can reject H0 for a significance level of 5%, and apart from those only in eight cases we cannot reject H0 at the 1% level. Therefore, there is strong evidence that the M-values are not uniformly distributed in all the indices under analysis, except for the Greek index. However, and as noted before (see section 3.2.2) this is not enough to prove or deny the existence of psychological barriers.

4.2 Barrier Tests

4.2.1 Barrier Proximity Test

In line with previous empirical tests and with financial theory, there are only two cases (out of 78) where β is negative and significant at a 10% level in the two lower levels (M 0.1 and M 1). Moreover, also in line with theory and previous studies, at higher levels we find several cases where β is negative and significant, even at the 1% significance level, being cases more abundant in the M 100 level (the one that had in theory the most likelihood of becoming a barrier).

R-squares are low, but in line with previous studies on stock indices, like

Bahng (2003). Tables 4, 5 and 6 (pages 21 to 23) provide the results. A deeper analysis follows.

Table 3 - Uniformity Test Results

Country	Statistic	M 0.1	M 1	M 10	M 100
Austria	**Kolmogorov (D) - Statistic value (adjusted)**	2.283	1.764	1.777	12.856
	P-value	0.000***	0.004***	0.004***	0.000***
Belgium	**Kolmogorov (D) - Statistic value (adjusted)**	1.503	2.369	2.362	7.953
	P-value	0.022**	0.000***	0.000***	0.000***
Europe	**Kolmogorov (D) - Statistic value (adjusted)**	1.832	1.708	2.173	4.300
	P-value	0.002***	0.006***	0.000***	0.000***
Finland	**Kolmogorov (D) - Statistic value (adjusted)**	1.502	1.612	1.681	8.684
	P-value	0.022**	0.011**	0.007***	0.000***
France	**Kolmogorov (D) - Statistic value (adjusted)**	1.598	2.292	1.583	7.747
	P-value	0.012**	0.000***	0.013**	0.000***
Germany	**Kolmogorov (D) - Statistic value (adjusted)**	2.732	2.169	2.282	15.367
	P-value	0.000***	0.000***	0.000***	0.000***
Greece	**Kolmogorov (D) - Statistic value (adjusted)**	1.278	1.201	1.093	5.457
	P-value	0.076*	0.112	0.183	0.000***
Ireland	**Kolmogorov (D) - Statistic value (adjusted)**	2.033	1.966	2.806	–
	P-value	0.001***	0.001***	0.000***	–
Italy	**Kolmogorov (D) - Statistic value (adjusted)**	1.721	1.637	1.560	0.860
	P-value	0.005***	0.009***	0.015***	0.450
Luxembourg	**Kolmogorov (D) - Statistic value (adjusted)**	1.499	1.365	1.712	12.643
	P-value	0.022**	0.048**	0.006***	0.000***
Portugal	**Kolmogorov (D) - Statistic value (adjusted)**	2.322	2.529	1.629	2.067
	P-value	0.000***	0.000***	0.010***	0.000***
Spain	**Kolmogorov (D) - Statistic value (adjusted)**	6.714	2.583	1.990	1.781
	P-value	0.000***	0.000***	0.001***	0.004***
The Netherlands	**Kolmogorov (D) - Statistic value (adjusted)**	2.133	1.953	7.254	–
	P-value	0.000***	0.001***	0.000***	–

*Each test was performed for the daily closing prices of each stock index. The table shows the results of a Kolmogorov test for uniformity of the distribution, the D column shows the test statistic results and the P-value column shows the marginal significance of these statistics. H0: uniformity, Ha non uniformity. Significant at the 1 percent level - ***; significant at the 5 percent level - **; significant at the 10 percent level - *.*

Table 4 - Barrier Proximity Test Results for the Strict Dummy

Strict Dummy												
Series	**M 0.1**			**M 1**			**M 10**			**M 100**		
	β	**p-value**	**R-square**	**β**	**p-value**	**R-square**	**β**	**p-value**	**R-square**	**β**	**p-value**	**R-square**
Austria	-0.004	0.289	0.011	-0.004	0.405	0.007	-0.009	0.037**	0.044	-0.006	0.138	0.002
Belgium	-0.006	0.361	0.009	-0.005	0.203	0.017	-0.009	0.149	0.021	-0.009	0.062	0.003
Europe	-0.005	0.323	0.010	-0.004	0.276	0.012	-0.007	0.195	0.017	-0.008	0.041**	0.004
Finland	-0.001	0.677	0.002	-0.004	0.329	0.010	-0.010	0.035**	0.045	-0.017	0.108	0.003
France	-0.007	0.186	0.018	-0.007	0.113	0.025	-0.005	0.360	0.009	-0.008	0.058*	0.004
Germany	-0.004	0.156	0.020	-0.002	0.525	0.004	-0.008	0.009***	0.068	-0.014	0.201	0.002
Greece	-0.002	0.487	0.005	-0.003	0.433	0.006	-0.010	0.027**	0.049	-0.012	0.129	0.002
Ireland	0.001	0.689	0.002	0.000	0.942	0.000	-0.010	0.003***	0.084	—	—	—
Italy	-0.005	0.468	0.005	0.000	0.991	0.000	-0.001	0.848	0.000	-0.005	0.500	0.000
Luxembourg	0.001	0.657	0.002	-0.001	0.920	0.000	-0.010	0.037**	0.044	-0.007	0.211	0.002
Portugal	-0.010	0.064	0.035	-0.005	0.198	0.017	-0.007	0.287	0.012	-0.006	0.232	0.001
Spain	-0.010	0.540	0.004	-0.009	0.044**	0.041	-0.008	0.152	0.021	-0.001	0.781	0.000
The Netherlands	-0.002	0.673	0.002	-0.006	0.106	0.026	-0.010	0.001***	0.102	—	—	—

*The table shows a synthesis of the results of the regression: $F(M) = \alpha + \beta D + \varepsilon$ where the dependent variable is the frequency of appearance of M-values, D is a dummy variable that takes the value 1 in the presence of a barrier; takes the value 1 at the 00 point. Significant at the 1 percent level - ***; significant at the 5 percent level - **; significant at the 10 percent level - *. See section 3.2.3 for more details.*

At the strict barrier level, we only find one negative β that is statistical significant (Spain at 5%), which clearly indicates that there are no barriers at those levels. However, at the two higher levels (especially at the M 10 level) we find several cases of statistically significant negative β values. Austria (5%), Finland (5%), Germany (1%), Greece (5%), Ireland (1%), Luxembourg (5%) and The Netherlands (1%) are the ones at the M 10 level. Europe (5%) and France (10%) are the cases at the M 100 level.

Table 5 - Barrier Proximity Test Results for the 98-02 Dummy

Series	98-02 Dummy											
	M 0.1			M 1			M 10			M 100		
	β	p-value	R-square	β	p-value	R-square	β	p-value	R-square	β	p-value	R-square
Austria	0.002	0.122	0.024	-0.001	0.745	0.001	0.001	0.525	0.004	0.001	0.125	0.002
Belgium	0.001	0.683	0.002	-0.001	0.500	0.005	0.001	0.820	0.001	-0.001	0.170	0.002
Europe	0.001	0.807	0.001	-0.001	0.779	0.001	0.001	0.808	0.001	0.004	0.000***	0.032
Finland	0.002	0.295	0.011	-0.002	0.284	0.012	0.000	0.889	0.000	-0.007	0.000***	0.017
France	0.001	0.659	0.002	0.000	0.982	0.000	-0.001	0.665	0.002	0.003	0.000***	0.013
Germany	0.001	0.539	0.004	-0.001	0.364	0.008	0.000	0.993	0.000	-0.005	0.006***	0.008
Greece	0.001	0.352	0.009	-0.001	0.535	0.004	0.000	0.920	0.000	-0.005	0.000***	0.013
Ireland	0.003	0.016***	0.058	-0.001	0.638	0.002	0.000	0.984	0.000	–	–	–
Italy	0.002	0.569	0.003	0.003	0.260	0.013	0.000	0.967	0.000	-0.001	0.516	0.000
Luxembourg	0.001	0.291	0.011	-0.001	0.751	0.001	0.001	0.557	0.004	-0.001	0.307	0.001
Portugal	0.001	0.570	0.003	0.001	0.421	0.007	-0.001	0.665	0.002	0.191	0.001***	0.002
Spain	0.006	0.395	0.007	0.003	0.195	0.017	0.000	0.916	0.000	0.000	0.943	0.000
The Netherlands	0.001	0.690	0.002	-0.001	0.583	0.003	-0.003	0.020***	0.054	–	–	–

*The table shows a synthesis of the results of the regression: $F(M) = \alpha + \beta D + \varepsilon$ where the dependent variable is the frequency of appearance of M-values, D is a dummy variable that takes the value 1 in the presence of a barrier; 98-02 barrier takes the value 1 in the 98, 99, 00, 01, 02 values. For the M 100 levels the same applies but between 980-020. Significant at the 1 percent level - ***; significant at the 5 percent level - **; significant at the 10 percent level - *. See section 3.2.3 for more details.*

At the 98-02 barrier, we find that all the negative significant β are at the higher levels, especially at the M 100 level (the one at the M 10 level, is at the highest level of the index), however there are fewer cases when compared to the strict barrier. The Netherlands (1%) at M 10; Finland (1%), Germany (1%), Greece (1%) at M 100 are the ones.

Table 6 - Barrier Proximity Test Results for the 95-05 Dummy

95-05 Dummy												
Series	**M 0.1**			**M 1**			**M 10**			**M 100**		
	β	**p-value**	**R-square**	**β**	**p-value**	**R-square**	**β**	**p-value**	**R-square**	**β**	**p-value**	**R-square**
Austria	0.001	0.394	0.007	0.000	0.836	0.000	0.000	0.777	0.001	0.002	0.000***	0.022
Belgium	0.001	0.731	0.001	-0.001	0.659	0.002	0.000	0.892	0.000	-0.001	0.012***	0.006
Europe	0.001	0.682	0.002	0.000	0.717	0.001	0.000	0.794	0.001	0.002	0.000***	0.026
Finland	0.001	0.501	0.005	0.000	0.752	0.001	0.000	0.870	0.000	-0.008	0.000***	0.048
France	0.000	1.000	0.000	0.000	0.868	0.000	0.000	0.816	0.001	0.003	0.000***	0.049
Germany	0.000	0.721	0.001	-0.001	0.527	0.004	0.000	0.823	0.001	-0.006	0.000***	0.025
Greece	0.001	0.441	0.006	-0.001	0.578	0.003	-0.001	0.492	0.005	-0.004	0.000***	0.021
Ireland	0.001	0.371	0.008	0.000	0.811	0.001	-0.001	0.370	0.008	—	—	—
Italy	0.001	0.625	0.002	0.000	0.790	0.001	-0.002	0.266	0.013	-0.001	0.146	0.002
Luxembourg	0.001	0.458	0.006	0.000	0.984	0.000	0.000	0.836	0.000	0.000	0.728	0.000
Portugal	0.000	0.842	0.000	0.000	0.751	0.001	0.000	0.912	0.000	0.002	0.002***	0.009
Spain	-0.001	0.858	0.000	0.001	0.649	0.002	0.000	0.978	0.000	-0.001	0.256	0.001
The Netherlands	-0.001	0.590	0.003	-0.002	0.204	0.016	-0.002	0.020	0.054	—	—	—

*The table shows a synthesis of the results of the regression: $F(M) = \alpha + \beta D + \varepsilon$ where the dependent variable is the frequency of appearance of M-values, D is a dummy variable that takes the value 1 in the presence of a barrier. Strict barrier takes the value 1 at the 00 point; 95-05 barrier takes the value 1 in the 95, 96, 97, 98, 99, 00, 01, 02, 03, 04, 05 values. For the M 100 levels the same applies but between 950-050. Significant at the 1 percent level - ***; significant at the 5 percent level - **; significant at the 10 percent level - *. See section 3.2.3 for more details.*

Again there are only significant negative β at the M 100 level. Belgium (1%), Finland (1%), Germany (1%) and Greece (1%) are those cases.

It is also curious to note that France is perfectly uniformed at the M 0.1 level.

Closing, Germany, Greece and Finland are according to this test the countries where the main index shows clear evidence of existence of psychological barriers, in the three countries case, at the M 100, so crossing round values of thousands.

4.2.2 Barrier Hump Tests

For the lower levels we find no evidence of the existence of barriers at those levels (as expected). Only at the largest level of analysis (the M 100 and the M 10 for those that do not have the M 100 level) we find results in line with the expected shape in the presence of psychological barriers. However, only a little minority of the results are statistically significant. Table 7 (page 24) presents the details, a deeper analysis follows.

Table 7 - Barrier Hump Test Results

Series	M 0.1			M 1			M 10			M 100		
	γ	P-value	R-square	γ	P-value	R-square	γ	P-value	R-square	γ	P-value	R-square
Austria	0.000000310	0.496	0.012	-0.000000034	0.956	0.001	0.000000049	0.934	0.001	0.000000012	0.000***	0 .213
Belgium	-0.000000175	0.836	0.001	0.000000043	0.940	0.013	0.000000360	0.663	0.003	-0.000000002	0.215**	0.105
Europe	0.000000150	0.826	0.002	0.000000170	0.748	0.003	0.000000250	0.718	0.003	0.000000010	0.000***	0.049
Finland	-0.000000017	0.968	0.003	0.000000013	0.982	0.002	-0.000000117	0.857	0.000	-0.000000068	0.000***	0.226
France	-0.000000008	0.991	0.000	0.000000075	0.894	0.005	-0.000000291	0.708	0.002	0.000000023	0.000***	0.218
Germany	-0.000000004	0.991	0.010	-0.000000118	0.806	0.003	-0.000000030	0.943	0.008	-0.000000076	0.000***	0.256
Greece	0.000000220	0.616	0.003	-0.000000178	0.746	0.002	-0.000000254	0.683	0.003	-0.000000010	0.005***	0.017
Ireland	0.000000250	0.552	0.016	-0.000000373	0.630	0.009	-0.000000567	0.227	0.028	—	—	—
Italy	0.000000320	0.705	0.001	0.000000230	0.739	0.005	-0.000000360	0.569	0.009	-0.000000004	0.192	0.002
Luxembourg	0.000000120	0.756	0.004	-0.000000040	0.956	0.001	0.000000160	0.809	0.001	0.000000008	0.000***	0.171
Portugal	0.000000054	0.941	0.004	0.000000150	0.758	0.015	0.000000160	0.850	0.001	0.000000009	0.000***	0.021
Spain	-0.000000047	0.983	0.007	0.000000300	0.612	0.011	-0.000000080	0.916	0.003	0.000000000	0.924*	0.000
The Netherlands	0.000000064	0.900	0.007	-0.000000704	0.174	0.020	-0.000000563	0.168	0.105	—	—	—

The table shows a synthesis of the results of the regression: $F(M) = \alpha + \delta M + \gamma M^2 + \varepsilon$ *where the dependent variable is the frequency of appearance of M-values, M refers to the M-values between 00 and 99 (000 and 999 for the M 100 level). Significant at the 1 percent level - ***; significant at the 5 percent level - **; significant at the 10 percent level - *. See section 3.2.4 for details.*

Belgium (5%), Finland (1%), Germany (1%) and Greece (1%) at the M 100 level are the ones that register the significant negative value that is in line with the shape indicative of psychological barriers.

It is important to note that Finland, Germany and Greece where the ones that according to the barrier proximity test had psychological barriers as well as Belgium also showed some support.

Increasing the importance of these results, Greece was the only country that we could not reject uniformity at all the lower levels, but we did reject uniformity for Greece at 1% for the M 100. Therefore, the Greek index is uniform at the lower levels but not at the M 100 and shows strong evidence of barriers at this level.

4.3 Conditional Effects

We can conclude that for all the return indicators in all the 13 indices, the signal does not change after crossing the barrier. There are mixed results in terms of magnitude, but in the majority of cases they tend to remain the same or decrease.

Moreover, the variance indicators, before a downward movement, are mainly negative, and after almost all of them are negative. Tables 8 to 11 (pages 26 to 29) present the results. A deeper analysis of the variance (the important indicator in terms of barriers) will follow; if round numbers are regarded as important we should find positive variance indicators before crossing (the market is turbulent) and negative after (the market is calmer).

Table 8 - Conditional Effects Regression Summary 5 Days (Return Equation)

5 Days		C	BD	AD	BU	AU
Austria	**Coefficient**	0.0000158	-0.00016	-0.00013	0.000105	0.000138
	P-value	0.000	0.000	0.000	0.000	0.000
Belgium	**Coefficient**	0.000011	-0.0000628	-0.0000746	0.0000814	0.0000286
	P-value	0.000	0.000	0.000	0.000	0.005
Europe	**Coefficient**	0.00001	-0.0000697	-0.0000893	0.0000671	0.0000502
	P-value	0.000	0.000	0.000	0.000	0.000
Finland	**Coefficient**	0.0000176	-0.00016	-0.00013	0.000144	0.000112
	P-value	0.000	0.000	0.000	0.000	0.000
France	**Coefficient**	0.00000589	-0.0000653	-0.0000573	0.0000554	0.0000529
	P-value	0.000	0.000	0.000	0.000	0.000
Germany	**Coefficient**	0.0000149	-0.0000785	-0.0000948	0.0000788	0.0000614
	P-value	0.000	0.000	0.000	0.000	0.000
Greece	**Coefficient**	0.0000193	-0.00025	-0.0002	0.000231	0.000118
	P-value	0.001	0.000	0.000	0.000	0.003
Ireland	**Coefficient**	0.0000319	-0.00027	-0.00026	0.000262	0.000186
	P-value	0.001	0.000	0.000	0.000	0.000
Italy	**Coefficient**	0.000000175	-0.00000488	-0.00000522	0.00000512	0.00000425
	P-value	0.568	0.000	0.000	0.000	0.000
Luxembourg	**Coefficient**	0.0000177	-0.00015	-0.00022	0.000243	0.00000963
	P-value	0.000	0.076	0.005	0.001	0.916
Portugal	**Coefficient**	0.00000277	-0.0000269	-0.0000181	0.0000195	0.0000218
	P-value	0.000	0.000	0.000	0.000	0.000
Spain	**Coefficient**	0.0000036	-0.0000267	-0.0000229	0.0000211	0.0000197
	P-value	0.000	0.000	0.000	0.000	0.000
The Netherlands	**Coefficient**	0.0001	-0.00026	-0.00077	0.000733	0.00015
	P-value	0.000	0.016	0.000	0.000	0.117

See the next table for notes.

Table 9 - Conditional Effects Regression Summary 5 Days (Variance Equation)

5 Days		C	RESID (-1)^2	GARCH (-1)	BD (variance equation)	AD (variance equation)	BU (variance equation)	AU (variance equation)
Austria	Coefficient	0.0000000001	0.0962	0.9101	-0.000000001	0.000000008	-0.000000005	0.000000001
	P-value	0.000	0.000	0.000	0.714	0.009***	0.022**	0.687
Belgium	Coefficient	0.000000003	0.2339	0.7198	0.000000001	0.000000001	-0.000000003	-0.000000002
	P-value	0.000	0.000	0.000	0.262	0.082*	0.000***	0.000***
Europe	Coefficient	0.0000000003	0.1147	0.8891	-0.0000000091	0.0000000147	-0.0000000011	-0.0000000004
	P-value	0.000	0.000	0.000	0.000***	0.000***	0.206	0.67
Finland	Coefficient	0.0000000003	0.0780	0.9269	0.0000000004	0.0000000071	0.0000000013	-0.0000000077
	P-value	0.000	0.000	0.000	0.897	0.019**	0.546	0.000***
France	Coefficient	0.0000000002	0.1029	0.9001	0.0000000006	0.0000000007	-0.0000000004	-0.0000000007
	P-value	0.000	0.000	0.000	0.115	0.047**	0.153	0.003***
Germany	Coefficient	0.0000000255	0.1500	0.5999	0.0000000047	-0.0000000017	-0.0000000208	-0.0000000068
	P-value	0.000	0.000	0.000	0.000***	0.016**	0.000***	0.000***
Greece	Coefficient	0.000000004	0.2051	0.7983	0.000000043	-0.000000014	-0.000000020	0.000000008
	P-value	0.000	0.000	0.000	0.000***	0.038**	0.000***	0.219
Ireland	Coefficient	0.000000003	0.0893	0.9107	-0.000000009	0.000000025	-0.000000012	-0.000000002
	P-value	0.000	0.000	0.000	0.131	0.000***	0.007***	0.693
Italy	Coefficient	0.0000000000026	0.1073	0.8948	-0.0000000000026	0.0000000000095	-0.0000000000078	0.0000000000003
	P-value	0.000	0.000	0.000	0.222	0.000***	0.000***	0.877
Luxembourg	Coefficient	0.0000000018	0.1096	0.883	0.0000000097	0.0000000120	-0.0000000393	0.000000052
	P-value	0.000	0.000	0.000	0.651	0.627	0.003***	0.001***
Portugal	Coefficient	0.0000000000364	0.125	0.8729	0.00000000004	0.0000000001050	-0.00000000011	0.0000000000382
	P-value	0.000	0.000	0.000	0.403	0.036**	0.000***	0.27
Spain	Coefficient	0.000000000019	0.0786	0.9263	-0.0000000001	0.0000000002	-0.00000000005	-0.000000000087
	P-value	0.000	0.000	0.000	0.026**	0.000***	0.081*	0.020**
The Netherlands	Coefficient	0.000000301	0.2569	0.7141	0.000000525	-0.000000498	-0.000000441	0.000000434
	P-value	0.000	0.000	0.000	0.000***	0.000***	0.000***	0.000***

This table and the previous one present the results of a GARCH (1,1) estimation of the form of $R_t = \beta_1 + \beta_2 BD_t + \beta_3 AD_t + \beta_4 BU_t + \beta_5 AU_t + \varepsilon_t \quad ; \quad \varepsilon_t \sim N(0, V_t) \quad ; \quad V_t = \alpha_1 + \alpha_2 V_{t-1} + \alpha_3 \varepsilon_{t-1}^2 + \alpha_4 BD_t + \alpha_5 AD_t + \alpha_6 BU_t + \alpha_7 AU_t + \eta_t$ *AU, BU, AD and BD are dummy variables. BU is for the 5 days prior to the index quote reaching a barrier from below, but before it breaches the barrier, AU for the 5 days after the barrier from below, BD and AD for the 5 days before and after breaching the barrier in a downwards direction. Therefore these dummies take the value 1 for the days noted, and zero otherwise. All values are for M 100 levels expect the AEX and the ISEQ 20 cases that are for the M 10 level, since it is the biggest level these ones reach.*

There are several cases where we have significant indicators both before and after crossing a barrier in a downward or in an upward movement. From those, the ones that show the signs in line with a barrier existence are Germany downward, Greece downward and The Netherlands downward. Finland shows upward evidence, but only after is significant.

Table 10 - Conditional Effects Regression Summary 10 Days (Return Equation)

10 Days		C	BD	AD	BU	AU
Austria	**Coefficient**	0.0000179	-0.0000813	-0.00012	0.0000755	0.0000789
	P-value	0.000	0.000	0.000	0.000	0.000
Belgium	**Coefficient**	0.0000109	-0.0000374	-0.0000431	0.00004	0.0000223
	P-value	0.000	0.000	0.000	0.000	0.027
Europe	**Coefficient**	0.0000106	-0.0000627	-0.0000676	0.0000559	0.0000369
	P-value	0.000	0.000	0.000	0.000	0.000
Finland	**Coefficient**	0.0000179	-0.00012	-0.0000928	0.000109	0.0000919
	P-value	0.000	0.000	0.000	0.000	0.000
France	**Coefficient**	0.00000598	-0.0000392	-0.0000352	0.0000336	0.0000314
	P-value	0.001	0.000	0.000	0.000	0.000
Germany	**Coefficient**	0.00000607	-0.0000317	-0.0000283	0.0000258	0.0000276
	P-value	0.000	0.000	0.000	0.000	0.000
Greece	**Coefficient**	0.000016	-0.00017	-0.00015	0.000156	0.000115
	P-value	0.008	0.000	0.000	0.000	0.002
Ireland	**Coefficient**	0.0000275	-0.00015	-0.00019	0.000191	0.0000992
	P-value	0.004	0.000	0.000	0.000	0.000
Italy	**Coefficient**	0.0000000805	-0.00000306	-0.00000341	0.00000365	0.00000258
	P-value	0.858	0.000	0.000	0.000	0.000
Luxemburg	**Coefficient**	0.0000176	-0.00013	-0.00014	0.000162	0.0000324
	P-value	0.000	0.005	0.002	0.003	0.560
Portugal	**Coefficient**	0.00000266	-0.0000189	-0.0000144	0.0000167	0.0000135
	P-value	0.000	0.000	0.000	0.000	0.000
Spain	**Coefficient**	0.00000613	-0.0000249	-0.0000165	0.0000123	0.0000215
	P-value	0.000	0.000	0.000	0.000	0.000
The Netherlands	**Coefficient**	0.0000693	-0.00049	-0.00036	0.000367	0.000371
	P-value	0.000	0.000	0.000	0.000	0.000

See the next table for notes.

Table 11 - Conditional Effects Regression Summary 10 Days (Variance Equation)

10 Days		C	RESID (-1)^2	GARCH (-1)	BD (variance equation)	AD (variance equation)	BU (variance equation)	AU (variance equation)
Austria	**Coefficient**	0.000000002	0.226	0.7852	0.000000002	0.000000011	-0.000000005	0.0000000006
	P-value	0.000	0.000	0.000	0.162	0.000***	0.000***	0.627
Belgium	**Coefficient**	0.0000000005	0.1182	0.8827	0.0000000003	0.000000001	-0.0000000009	-0.000000001
	P-value	0.000	0.000	0.000	0.401	0.006***	0.005***	0.011**
Europe	**Coefficient**	0.0000000003	0.1108	0.8947	-0.000000001	0.000000004	-0.0000000004	-0.0000000007
	P-value	0.000	0.000	0.000	0.003***	0.000***	0.167	0.016**
Finland	**Coefficient**	0.0000000005	0.079	0.9262	-0.000000001	0.000000007	0.000000002	-0.000000007
	P-value	0.000	0.000	0.000	0.522	0.000***	0.207	0.000***
France	**Coefficient**	0.0000000002	0.1017	0.9011	-0.0000000002	0.0000000009	-0.0000000001	-0.0000000005
	P-value	0.000	0.000	0.000	0.332	0.000***	0.595	0.000***
Germany	**Coefficient**	0.0000000001	0.1113	0.9	0.0000000002	0.0000000002	-0.0000000002	-0.0000000002
	P-value	0.000	0.000	0.000	0.015**	0.002***	0.000***	0.000***
Greece	**Coefficient**	0.0000000005	0.0893	0.9169	0.00000001	0.000000004	-0.000000008	0.000000001
	P-value	0.001	0.000	0.000	0.003***	0.338	0.003***	0.721
Ireland	**Coefficient**	0.000000003	0.0866	0.9114	-0.00000002	0.00000003	-0.000000001	-0.000000005
	P-value	0.000	0.000	0.000	0.000***	0.000***	0.491	0.007***
Italy	**Coefficient**	0.000000000004	0.1382	0.8549	-0.000000000003	0.000000000008	-0.000000000005	0.000000000001
	P-value	0.001	0.000	0.000	0.007***	0.000***	0.000***	0.065*
Luxemburg	**Coefficient**	0.000000002	0.1071	0.8852	0.0000000003	0.00000002	-0.000000006	0.000000009
	P-value	0.000	0.000	0.000	0.948	0.012**	0.001**	0.000***
Portugal	**Coefficient**	0.00000000004	0.134	0.8648	0.00000000003	0.00000000008	-0.00000000006	0.00000000002
	P-value	0.000	0.000	0.000	0.169	0.000***	0.000***	0.323
Spain	**Coefficient**	0.000000001	0.1904	0.7428	0.0000000004	0.0000000001	-0.000000001	-0.0000000002
	P-value	0.000	0.000	0.000	0.000***	0.092*	0.000***	0.000***
The Netherlands	**Coefficient**	0.00000001	0.0845	0.9222	0.00000006	0.00000003	-0.00000007	-0.00000002
	P-value	0.000	0.000	0.000	0.000***	0.099*	0.000***	0.323

Table presents the results of a GARCH (1,1) estimation of the form of $R_t = \beta_1 + \beta_2 BD_t + \beta_3 AD_t + \beta_4 BU_t + \beta_5 AU_t + \varepsilon_t$; $\varepsilon_t \sim N(0, V_t)$; $V_t = \alpha_1 + \alpha_2 V_{t-1} + \alpha_3 \varepsilon_{t-1}^2 + \alpha_4 BD_t + \alpha_5 AD_t + \alpha_6 BU_t + \alpha_7 AU_t + \eta_t$ *AU, BU, AD and BD are dummy variables. AU is for the 10 days prior to the index quote reaching a barrier from below, but before it breaches the barrier, AU for the 10 days after the barrier from below, BD and AD for the 10 days before and after breaching the barrier in a downwards direction. Therefore these dummies take the value 1 for the days noted, and zero otherwise. All values are for M 100 levels expect the AEX and the ISEQ 20 cases that are for the M 10 level, since it is the biggest level these ones reach.*

There are several cases where we have significant indicators both before and after crossing a barrier in a downward or in an upward movement. From those, there are no cases showing evidence of a barrier. Finland shows upward evidence, but only after is significant.

These results are clear evidence that 10 trading days are too apart from the main event to be impacted by it, indicating that the impact of the barrier crossing lasts from around 5 trading days.

Moreover, Germany and Greece repeat again as the ones with evidence of a barrier; Finland with lower evidence here was also found to have barriers in the previous tests; and The Netherlands, even though with weaker evidence than previously mentioned, still showed evidence in previous tests of barrier existence.

4.3.1 Conditional Effects Difference Tests

Complementing the previous test, tables 12 (page 31) and 13 (page 32) show the results for tests of difference of return and variance before and after crossing barriers in both directions. A deeper analysis follows.

In terms of mean return we find statistically significant differences before and after an upward crossing in Belgium (1%), France (5%), Greece (10%), Ireland (10%), Luxembourg (10%) and The Netherlands (1%); in terms of downward movements Portugal (5%) and The Netherlands (1%) are the only cases.

In terms of variance we find statistically significant differences before and after an upward crossing in Finland (5%), Germany (1%), Greece (1%), Italy (5%), Luxembourg (1%), Portugal (5%) and The Netherlands (1%); in terms of a downward movement Europe, France, Germany, Greece Ireland, Italy, Spain and The Netherlands (all at 1%, except France at 5%).

Table 12 - Difference Tests for Conditional Moments 5 Days

5 Days Dummy		H1: There is no significant difference in the conditional mean return before and after an upward crossing of a psychological barrier;	H2.There is no significant difference in the difference in conditional mean return before and after a downward crossing of a psychological barrier;	H3.There is no significant difference in the difference in conditional variance before and after an upward crossing of a psychological barrier;	H4.There is no significant difference in the difference in conditional variance before and after downward crossing of a psychological barrier.
Austria	**Chi-square**	0.937	0.589	1.754	2.416
	P-value	0.333	0.443	0.185	0.120
Belgium	**Chi-square**	10.819	0.780	0.095	0.187
	P-value	0.001***	0.377	0.758	0.665
Europe	**Chi-square**	0.663	0.619	0.153	142.942
	P-value	0.416	0.431	0.696	0.000***
Finland	**Chi-square**	0.766	0.713	5.040	1.331
	P-value	0.381	0.398	0.025**	0.249
France	**Chi-square**	0.048**	0.449	0.556	0.011**
	P-value	0.827	0.503	0.456	0.916
Germany	**Chi-square**	1.046	0.948	94.771	22.164
	P-value	0.307	0.330	0.000***	0.000***
Greece	**Chi-square**	3.798	0.580	17.303	13.433
	P-value	0.051*	0.446	0.000***	0.000***
Ireland	**Chi-square**	3.205	0.121	1.156	7.557
	P-value	0.073*	0.728	0.282	0.006***
Italy	**Chi-square**	1.791	0.199	5.777	8.949
	P-value	0.181	0.656	0.016**	0.003***
Luxembourg	**Chi-square**	2.889	0.327	10.252	0.003
	P-value	0.089*	0.567	0.001***	0.959
Portugal	**Chi-square**	0.531	5.635	6.214	0.507
	P-value	0.466	0.018**	0.013**	0.476
Spain	**Chi-square**	0.198	1.078	0.251	15.568
	P-value	0.657	0.299	0.617	0.000***
The Netherlands	**Chi-square**	13.999	19.349	33.011	248.986
	P-value	0.000***	0.000***	0.000***	0.000***

*Results are for a Chi-square test of the null hypothesis shown. Significant at the 1 percent level - ***; significant at the 5 percent level - **; significant at the 10 percent level - *.*

Table 13 - Difference Tests for Conditional Moments 10 Days

10 Days Dummy		H1: There is no significant difference in the conditional mean return before and after an upward crossing of a psychological barrier;	H2.There is no significant difference in the difference in conditional mean return before and after a downward crossing of a psychological barrier;	H3.There is no significant difference in the difference in conditional variance before and after an upward crossing of a psychological barrier;	H4.There is no significant difference in the difference in conditional variance before and after downward crossing of a psychological barrier.
Austria	**Chi-square**	0.025	1.132	10.353	14.541
	P-value	0.874	0.287	0.001***	0.000***
Belgium	**Chi-square**	1.800	0.155	1.539	0.036
	P-value	0.180	0.694	0.215	0.849
Europe	**Chi-square**	1.816	0.684	53.880	0.443
	P-value	0.178	0.408	0.000***	0.506
Finland	**Chi-square**	0.384	0.684	14.041	7.464
	P-value	0.536	0.408	0.000***	0.006***
France	**Chi-square**	0.049	0.154	10.796	3.382
	P-value	0.826	0.695	0.001***	0.066*
Germany	**Chi-square**	0.115	0.306	0.108	0.065
	P-value	0.735	0.580	0.742	0.799
Greece	**Chi-square**	0.684	0.177	2.196	1.192
	P-value	0.408	0.674	0.138	0.275
Ireland	**Chi-square**	8.551	0.977	1.486	113.706
	P-value	0.004***	0.323	0.223	0.000***
Italy	**Chi-square**	3.043	0.264	31.065	14.875
	P-value	0.081*	0.608	0.000***	0.000***
Luxembourg	**Chi-square**	1.960	0.019	16.499	2.420
	P-value	0.162	0.891	0.000***	0.120
Portugal	**Chi-square**	1.714	2.378	9.090	1.963
	P-value	0.191	0.123	0.003***	0.161
Spain	**Chi-square**	8.594	6.489	144.569	79.987
	P-value	0.003***	0.011**	0.000***	0.000***
The Netherlands	**Chi-square**	0.001	1.878	1.124	2.816
	P-value	0.973	0.171	0.289	0.093*

*Results are for a Chi-square test of the null hypothesis shown. Significant at the 1 percent level - ***; significant at the 5 percent level - **; significant at the 10 percent level - *.*

In terms of mean return we find statistically significant differences before and after an upward crossing in Italy (10%), Ireland (1%) and Spain (1%); in terms of downward movements Spain (5%) is the only case.

In terms of variance we find statistically significant differences before and after an upward crossing in Austria, Europe, Finland, France, Italy, Luxembourg, Portugal and Spain (all at 1%); in terms of a downward movement Austria (1%), Finland (1%), France (10%), Ireland (1%), Italy (1%), Spain (1%) and The Netherlands (10%).

The disparity from this results and all the previous ones reinforces the idea that 10 days it too big of a range to study the impact of barriers.

Even though several other countries showed a statistically significant difference, the four that almost systematically and in every test showed evidence of barriers were again strongly significant at this test (which is a test to confirm the results of the previous ones): Finland, Germany, Greece and The Netherlands.

5. Conclusion

In a world where stock indices get as much attention from the news as major macroeconomic events it is strange to find so little financial research on this subject. This study tried to contribute to decrease that attention gap from financial study to the psychological barrier phenomenon.

In a reality where agents are heterogeneous and have cognitive limitations as well as are affected by sentiments, the theory of full rationality and market efficiency does not fully apply (even though mainstream financial theory has its merits, perfect does not exist). There have been several studies that suggest the existence of market inefficiencies and this is another one. One where our millennial numbering system creates the abnormality almost by itself, if there were not round numbers this effect would not exist.

In this thesis we consider a range and data studying 13 stock indices from the Eurozone since their creation (some of the data includes more than 50 years) as well as is, to our knowledge the first on psychological barriers in stock indices to include the post 2008 crisis period.

Moreover, we performed a wide set of tests (all the major tests used on psychological barriers were implemented) with several improvements.

First, we did the uniformity test and the barrier proximity and barrier hump test also for the lower levels of M values so to reinforce the results. One could point that the effect did happen on lower levels and so was not caused by cognitive biases, with this we proved that it was only at the higher levels that the indicative shapes of barriers appeared and not at the lower.

Second, for the M 100 level we did the test with 1000 numbers instead of 100, so using 3 digits to increase accuracy.

Third, we did the conditional effects test both for 5 and 10 days periods. To our knowledge it is the first time that someone has done that comparison on any asset class. This upgrade turned out to be crucial since we concluded that 10 days was too large of period for studying psychological barriers. Our data indicates that the phenomenon's impact on traders lasts less than 10 days.

Even though we did not find clear evidence of psychological barriers in Austria, Belgium, Europe, France, Ireland, Italy, Luxembourg, Portugal and Spain, since the results are mixed for these countries we cannot exclude that their indices suffer from psychological barriers. No distribution is uniform, the larger M-values follow the expected shape in the presence of barriers and off course the M 0.1 and M 1 show much less significant indicators of barrier.

However, there are four countries whose indices suffer from psychological barriers: Finland, Germany, Greece and The Netherlands. The Greek FTSE/ATHEX LARGE CAP and German DAX 30 cases are the strongest since they showed evidence of psychological barriers in every test performed, in almost every case at 1% significance levels. This evidence shows clear impact of sample change since Cyree et al. (1999) do not find that result for the DAX 30 as well as find evidence of barriers in the CAC 40, which we do not find. We must state that the Greek case is so strong that the lower levels were uniformly distributed with the M 100 level not being uniformly distributed.

It is also interesting to note that at the conditional effects differential tests results are slightly stronger in terms of upward movements, but for most of the indices where we find barriers consistently across every test the evidence of barrier existence is in downward crossings.

From our study it is clear that these four markets are not efficient and that one might profit from this anomaly, an additional study testing if a portfolio management strategy inputting this anomaly on that four markets would turn a profit after transaction costs as well as test it by itself it would beat the market.

Further study in terms of conditional moments is recommended, as well as a study of the indices' components since they are the ones transitioned directly and if we find barriers in the index we might also find it in its components. Moreover, a study on how many days the effect of crossing the barrier lasts as well as at what proximity of the barrier do investors start to be influenced by would be extremely interesting and recommendable from our results.

Moreover, studies using data only from the 2008 crisis are encouraged due to the high importance of psychological effects in that time frame. As well as, since the indices are composed of stocks, there might be also be barrier effects on those securities so we also recommend that our methodology should be implemented on studying psychological barriers on the individual securities.

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